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Analysis of Injury Severity Caused by Flight Motor Overpressure of the Javelin Antiarmor Missile

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The Javelin is an antiarmor missile system designed to replace the Dragon. A rare malfunction of the missile involves overpressure of the flight motor. Data on the number, mass, and velocity of large debris items were determined by simulation of the malfunction. This report reviews the severity of injuries to the gunner or assistant gunner expected from a malfunction.

The probability of being struck by a missile fragment was calculated as 96 in 100. The most severe injuries include a head or groin injury from either of the two largest debris items or an eye injury from any debris fragment. Other possible injuries include upper extremity fractures or superficial lacerations. Specific steps to reduce the hazard and improve personal protection will reduce the severity of injuries.

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Introduction

The Javelin is a man-portable, shoulder-launched, antiarmor weapon system for attacking and destroying armored tank targets. It will replace the Dragon, the current antitank weapon. The Javelin system features reduced blast signature, fire and forget targeting, and twice the range of the Dragon.

The Javelin system consists of a command launch unit (CLU) and missile round. The CLU includes a sight system for surveillance, target identification, and target lockon. The missile round consists of the launch tube assembly, battery/ coolant unit, and missile. The missile is shown in Figure 1. The battery/coolant unit supplies electrical power to initiate launch and cooling gas to precool the missile seeker before launch. Estimated system weights are presented in Table 1 (Texas Instruments, 1992).

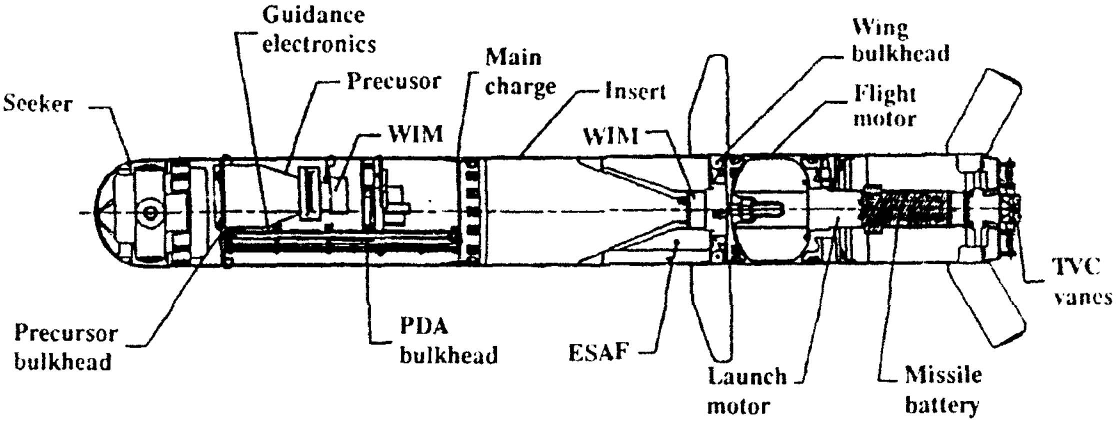

Figure 1. Javelin missile configuration.

Table 1.

Estimated system weights.

Component	Weight (kg)	Weight (lbs)
Command launch unit	6.38	14.07
Launcher	4.15	9.16
Missile	11.78	25.98

The missile system is operated by a gunner and assistant gunner. When firing the missile, both soldiers will wear the Personnel Armor System for Ground Troops (PASGT) helmet, battle dress uniform (BDU), and Kevlar® protective vest. The gunner will be positioned behind the missile with his face protected by the face shield of the command launch unit. The position of the assistant gunner has not been decided.

A rare malfunction of the Javelin missile involves in-flight overpressure of the flight motor shortly after ejection of the missile from the launch tube. This malfunction produces debris that may pose a hazard to the gunner or assistant gunner. In conjunction with the Javelin test program, the malfunction was simulated in three tests by plugging the nozzle of the flight motor on a test missile. The test articles included inert launch motors and live flight motors. For each test, high-speed cameras and debris panels were placed around the missile. This generated information on the likely debris items, scatter pattern, and velocity.

The simulated malfunction produces several small debris items including pieces of circuit board and composite materials with low mass. The large debris items include the (a) missile battery, (b) launch motor housing, (c) CAS motors [4 each], (d) control fins [4 each], and (e) TVC vane [4 each]. These items are shown in Figures 2-6 and the rearward velocity from a simulated malfunction (25 January 1993) is shown in Table 2.

Table 2.

Rearward velocity of overpressure debris*.

Debris item	Velocity (m/s)	Velocity (fps)
Missile battery	19.1	62.8
Launch motor	17.0	55.9
housing	24.0	78.6
CAS motor (#1)	18.1	59.4
CAS motor (#2)	18.1	59.4
CAS motor (#3)	17.2	56.3
Control fin (#1)	34.6	113.6
TVC vane (#1)	22.6	74.2
TVC vane (#2)		

* Debris velocity calculated by subtracting nominal missile velocity (44 fps) from debris velocity 4 feet behind the missile in a static test.

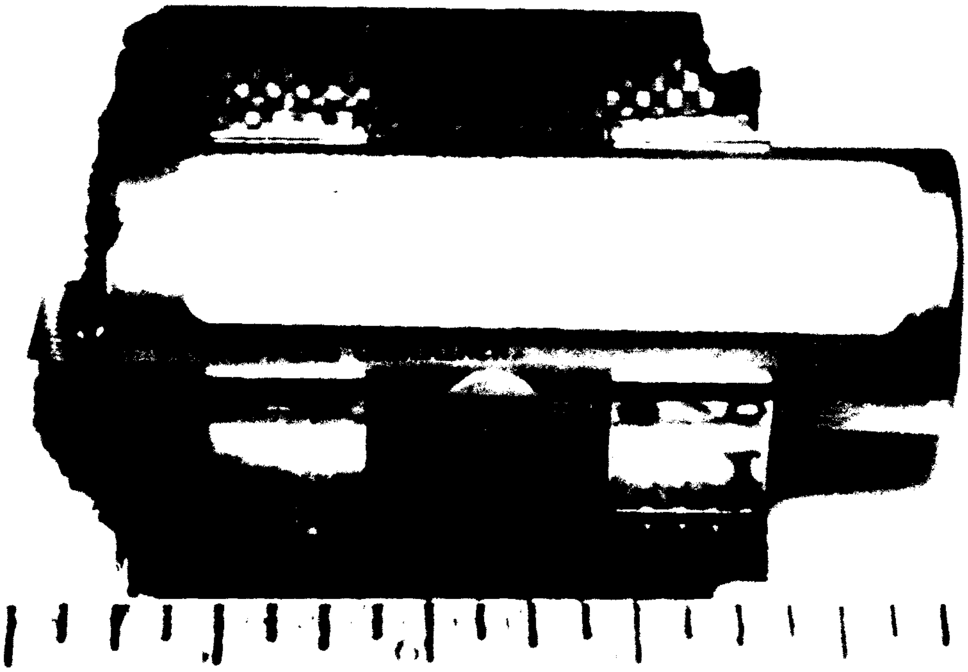

Figure 2. Missile battery.

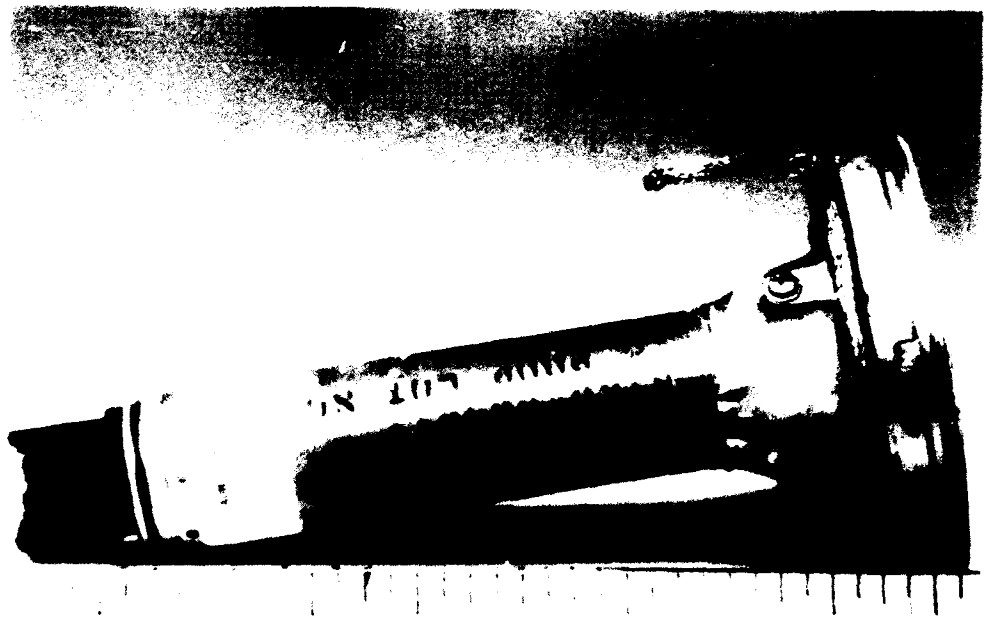

Figure 3. Launch motor housing.

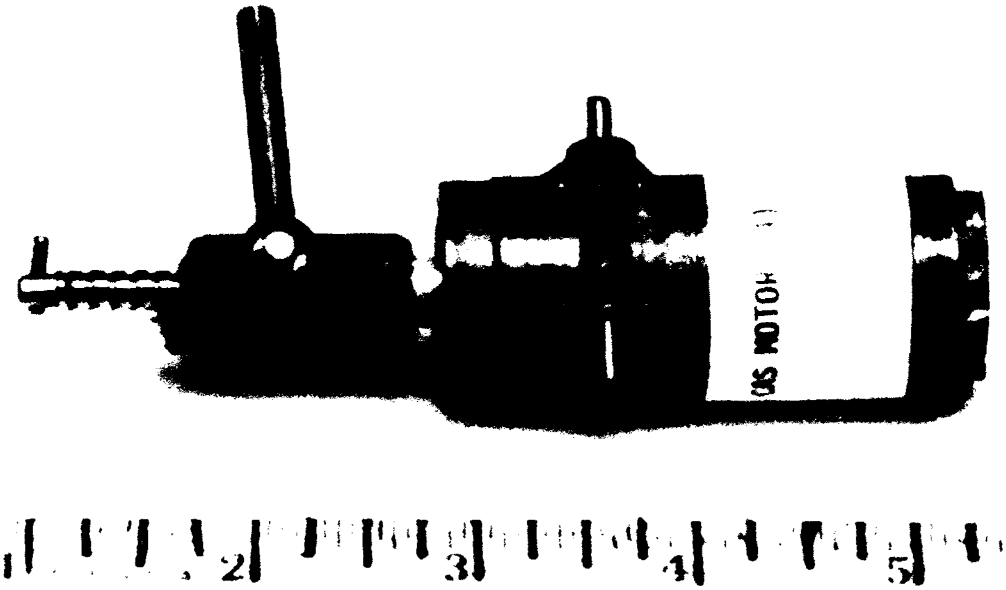

Figure 4. CAS motor.

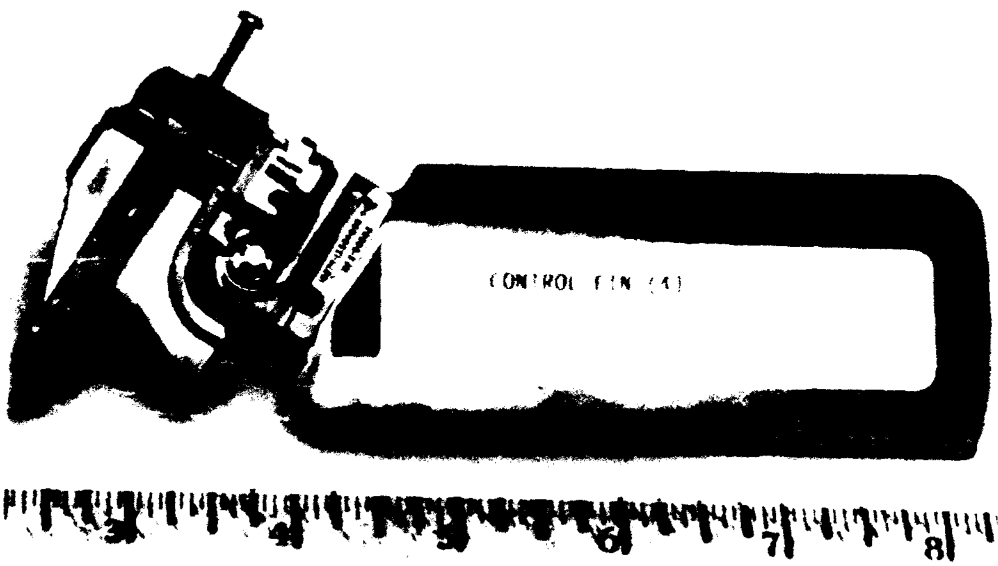

Figure 5. Control fin.

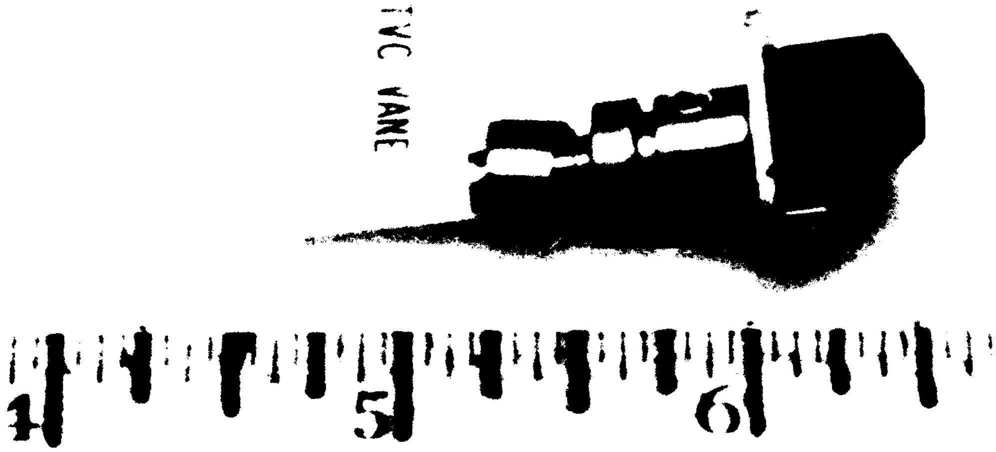

Figure 6. TVC vane.

The purpose of this paper is to discuss the type and severity of injuries that would occur to the gunner and assistant gunner from in-flight overpressure of the missile. The System Safety Working Group of the Javelin program office requested this information to support the hazard assessment of an overpressure malfunction, in accordance with MIL-STD 882D (Department of Defense, 1984).

Materials and methods

Probability of debris strike

Javelin missile test firings showed the flight motor ignites 0.4 seconds after the missile is launched. At that time the missile was 1.5 meters above the ground, 4.6 m (15 feet) down range, and had achieved a forward velocity of 13.4 m/s (44 fps). Figure 7 shows the relative distance between the gunner, assistant gunner (possible position), and missile at the time of malfunction. The position of the assistant gunner during missile launch has not been decided, but it should not be closer to the missile than the gunner.

Malfunction simulations show only a small probability that the gunner will be struck by a piece of debris. In these tests, the launch motor and battery have gone to the right and left side of the gunner position, respectively. If the debris spreads randomly within a cone shaped area behind the missile (60 degrees wide by 60 degrees elevation), most debris items will strike the ground or miss the soldiers. The probability that a piece of debris will strike a soldier is estimated by dividing the surface area of the soldier by the surface area of the 15-foot (4.6 m) radius sphere contained within the impact cone. The probability of being struck by at least one large piece of debris is the sum of the probabilities for each single piece of debris.

The frontal surface area of a prone, kneeling (or sitting), and standing soldier was calculated for the 95th percentile male soldier using the data collected by Gordon et al. (1989). The calculated surface areas are shown in Table 3.

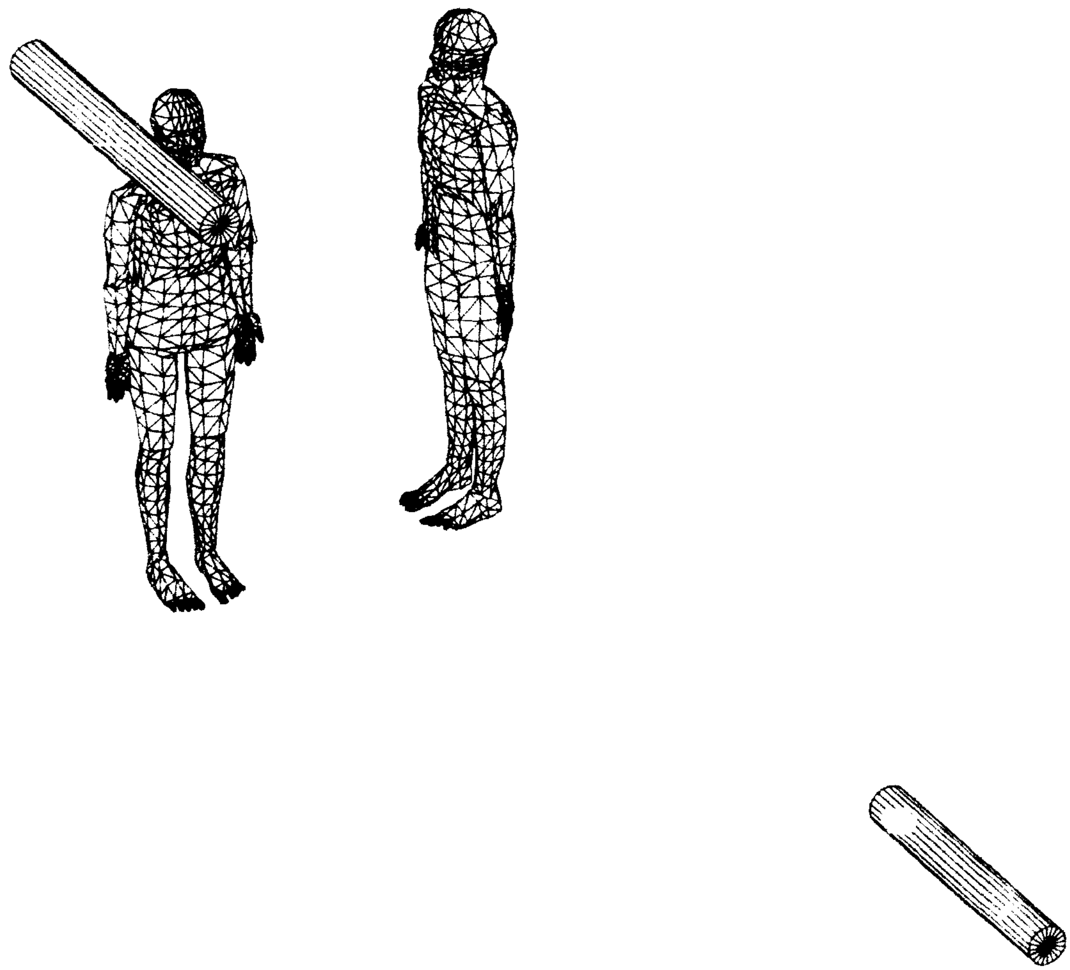

Figure 7. Schematic showing standing position for gunner, assistant gunner (exact duty position not yet decided), and missile at time of malfunction.

Table 3.

Calculated frontal surface area.

Position	Method	Surface area (sq cm)
Prone	Chest depth x bideltoid breadth	1500
Kneeling/sitting	Chest height x bideltoid breadth	7326
Standing (face to missile)	Stature x bideltoid breadth	9982
Standing (side to missile)	Stature x chest depth	5234

Calculation of debris impact energy

Debris items that strike the gunner or assistant gunner can produce injury. The impact energy for debris that strikes the body (and does not deflect off or pass through the body) is equal to the kinetic energy of the item. The kinetic energy for each debris item is half the mass times the square of the velocity.

Results

Given a homogeneous scatter of debris in the area behind the missile malfunction, the worst case probability of being struck by a large debris item is 96 in 100. The probability of being struck by debris decreases as the surface area exposed to the blast decreases. A calculated strike probability for each position is shown in Table 4. The probability of any debris strike causing injury is small.

The kinetic energy for each debris item recovered from a malfunction simulation is presented in Table 5.

Table 4.

Probability of being struck by a specific large debris item or any large debris item.

Position	Single item (N=1)	Any item (N=14)
Prone	0.010	0.144
Kneeling or sitting	0.050	0.703
Standing (face to missile)	0.068	0.958
Standing (side to missile)	0.036	0.502

Table 5.

Kinetic energy of large debris items.

Debris item	Mass (g)	Kinetic energy (J)
Missile battery	376	68.5
Launch motor housing	825	119.2
CAS motor (#1)	130	37.4
CAS motor (#2)	130	21.2
CAS motor (#3)	130	21.2
Control fin (#1)	64	9.5
TVC vane (#1)	19	11.1
TVC vane (#2)	19	4.75

Discussion

The method used to calculate the probability of being struck by debris assumes that each fragment is randomly expelled through the strike area. Data on the actual scatter pattern for each fragment will provide a more accurate estimate of which debris items will strike the gunner or assistant gunner.

The injury produced by a projectile is related to the shape of the projectile, type of tissue struck by the projectile, and energy deposited in the tissue (Fackler, 1987; Mendelson, 1991). The kinetic energy of the projectile is a measure of the energy that must be absorbed by the tissue to stop the movement of the object. For example, the kinetic energy of a baseball thrown at 70 miles per hour is 73 J and the kinetic energy of a 55 grain bullet fired by an M-16 (988 m/s) is 945 J (Grolier, 1992; Barach, Tommlanovich, and Nowak, 1986).

The most severe credible injury that will occur with an overpressure malfunction is an eye injury. A large debris item can pierce the eye and even small fragments from a circuit board or composite casing can lacerate the cornea. The worst credible eye injury would be critical (category II) in severity. Since the gunner's face is protected by the command launch unit, only the assistant gunner is exposed to this hazard and only if he is looking at the missile when it malfunctions. This injury can be prevented by using safety devices (goggles or a face shield) to protect the assistant gunner, or with procedures or training that prevent him from looking at the missile early in flight.

The two largest items of debris (launch motor housing and missile battery) may have sufficient impact energy to cause significant injury. If the launch motor housing or battery strikes the PASGT helmet, it can transmit sufficient energy to cause a closed head injury. This injury will produce several minutes of unconsciousness and, rarely, seizures. In addition, the same items will cause significant tissue damage if they strike the unprotected groin. These are both considered critical (category II) injuries. The head injury hazard can be reduced by adding impact attenuation characteristics (such as an energy-absorbing liner) to the PASGT helmet. The groin injury could be prevented with strike protection.

Other credible injuries from these two items include deep tissue bruising and fractures if the debris strikes the unprotected hand or forearm. There will be deep bruising in the lower extremities, but fractures are unlikely. These injuries are considered marginal (category III) in severity.

The remaining debris items have less kinetic energy and are not expected to produce the closed head injury, significant groin injury, or fractures possible with the launch motor housing or missile battery. They will cause some tissue bruising and the irregular and sharp surfaces on these debris items will penetrate the BDU and cause lacerations. These injuries are considered marginal (category III) in severity.

Conclusions

Random dispersion of debris from an overpressure malfunction poses only a small risk that the gunner or assistant gunner will be injured. The worst credible injuries include eye injury, closed head injury, and blunt trauma to the groin. Eye injuries can be reduced by adding eye protection for the assistant gunner. The head injury and groin injury hazard will be eliminated if the launch motor housing and battery can be prevented from striking the gunner or assistant gunner. Other approaches include the addition of an energy-attenuating liner in the PASGT helmet and protection of the groin. These injuries are critical (category II) in severity.

The missile launch tube and battery can cause deep tissue bruising and fractures if they strike the forearm or hands. The remaining debris items will produce bruising and superficial lacerations if they strike areas of the body protected only by the BDU. These injuries are marginal (category III) in severity.

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